Comparison of the Effects of RAS vs. Kain-Fritsch Convective Schemes on Katrina Forecasts with GEOS-5

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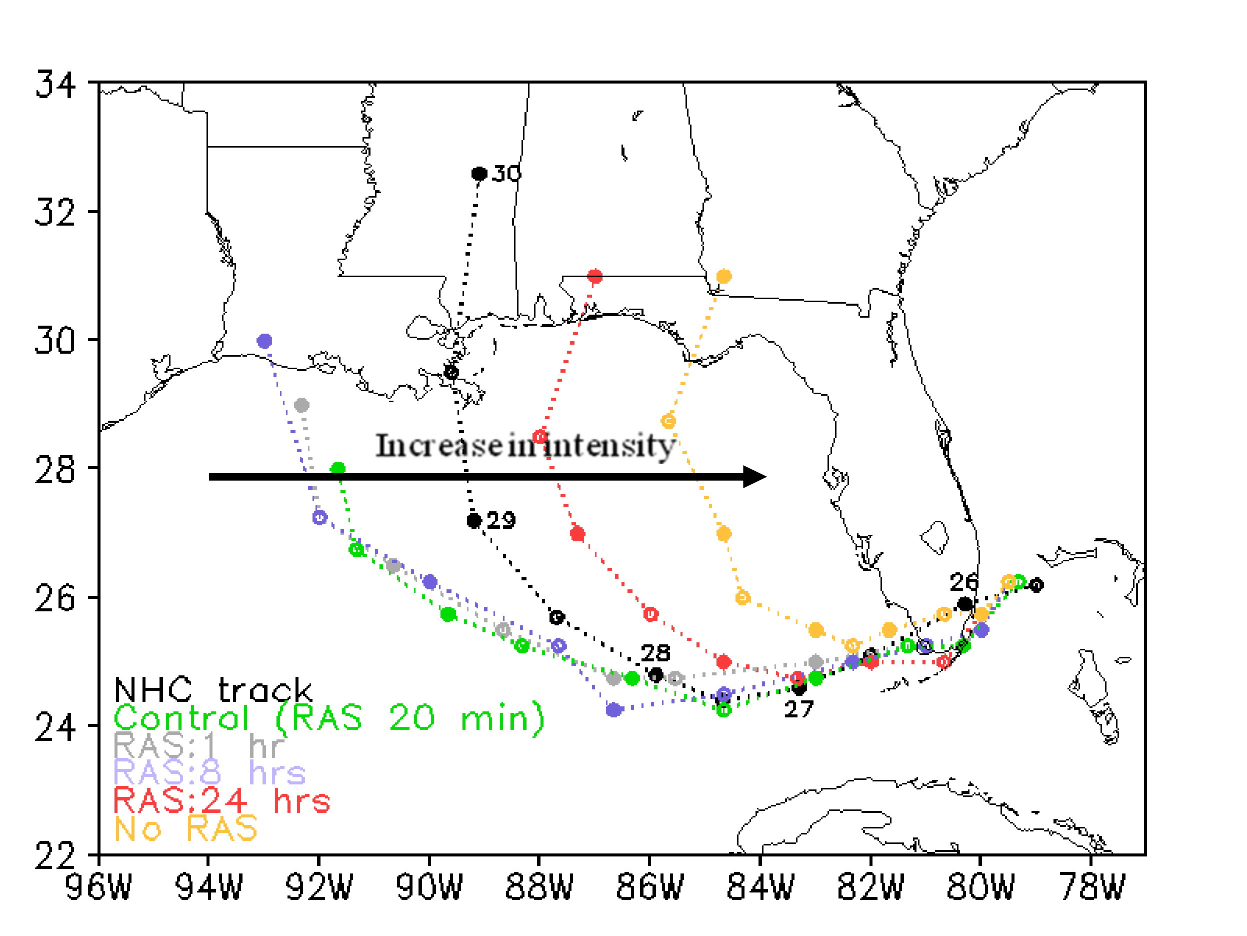
Background

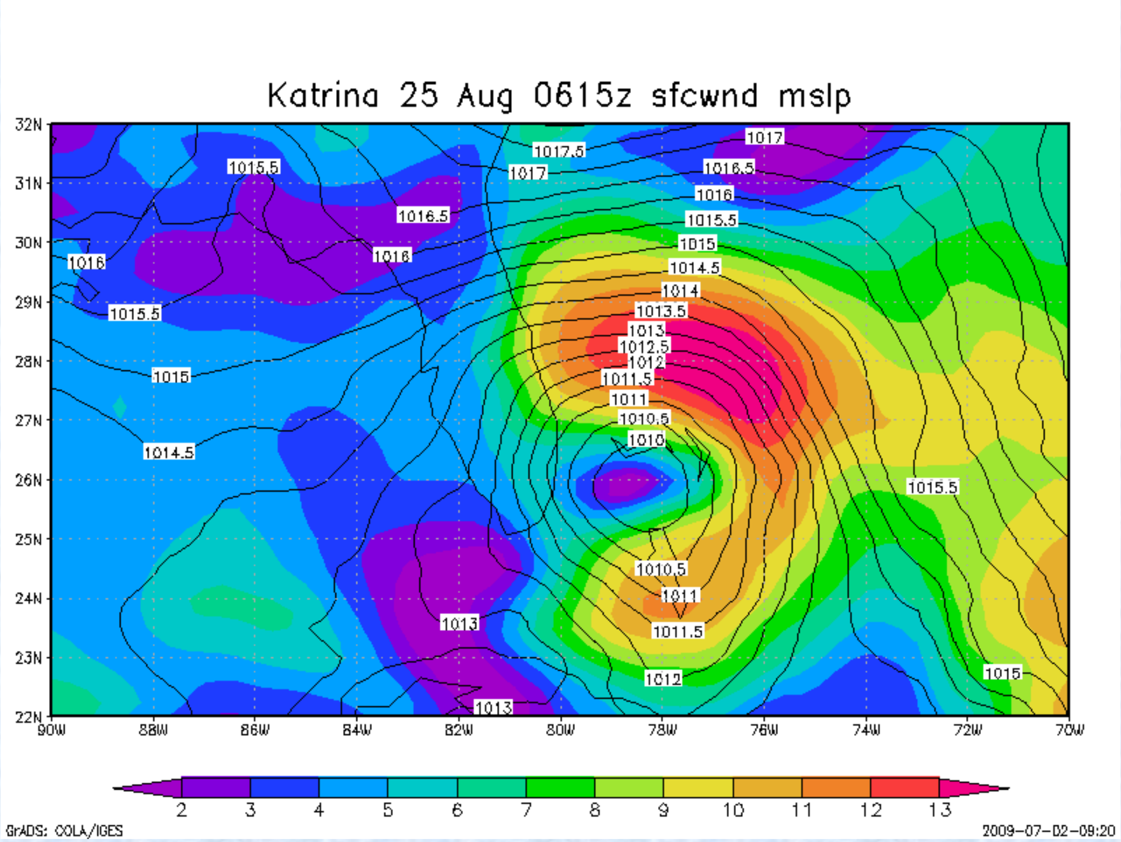
- Although 0.25 deg resolution still does not well resolve an intense hurricane vortex (radius of max winds ~20km), based on experience at somewhat coarser resolution, one might expect to make “reasonable” forecasts with a global model at that resolution for both climate and weather purposes
- As global models close in on mesoscale resolution, it is necessary to consider the appropriateness of convective parameterization schemes
  - 0.25-degree resolution is not yet adequate to explicitly resolve cumulus convection
  - Schemes appropriate for coarser resolution may no longer be appropriate for “high” resolution
  - For example, the Arakawa-Schubert scheme (including the “relaxed” one, or RAS) becomes difficult to justify
    - Presumed statistical equilibrium may not exist
    - Experience with tropical storm simulation indicates under-prediction (basis for the present work)
  - The Kain-Fritsch (K-F) scheme was designed for models with ~25-50 km resolution, although some modifications for tropical convection were necessary for this work
    - Identification of “maritime tropical” is done via test of pressure difference between source level and LCL (50 hPa -> 100 hPa, linear interpolation between)
    - Reduce updraft radius, increase required W for trigger
- Cohen has implemented K-F in GEOS-5, targeting especially high-resolution simulations. A case study is shown here of the Katrina hurricane of 2005 at 0.25 degrees latitude resolution.

Bacmeister et al. results that motivated this work

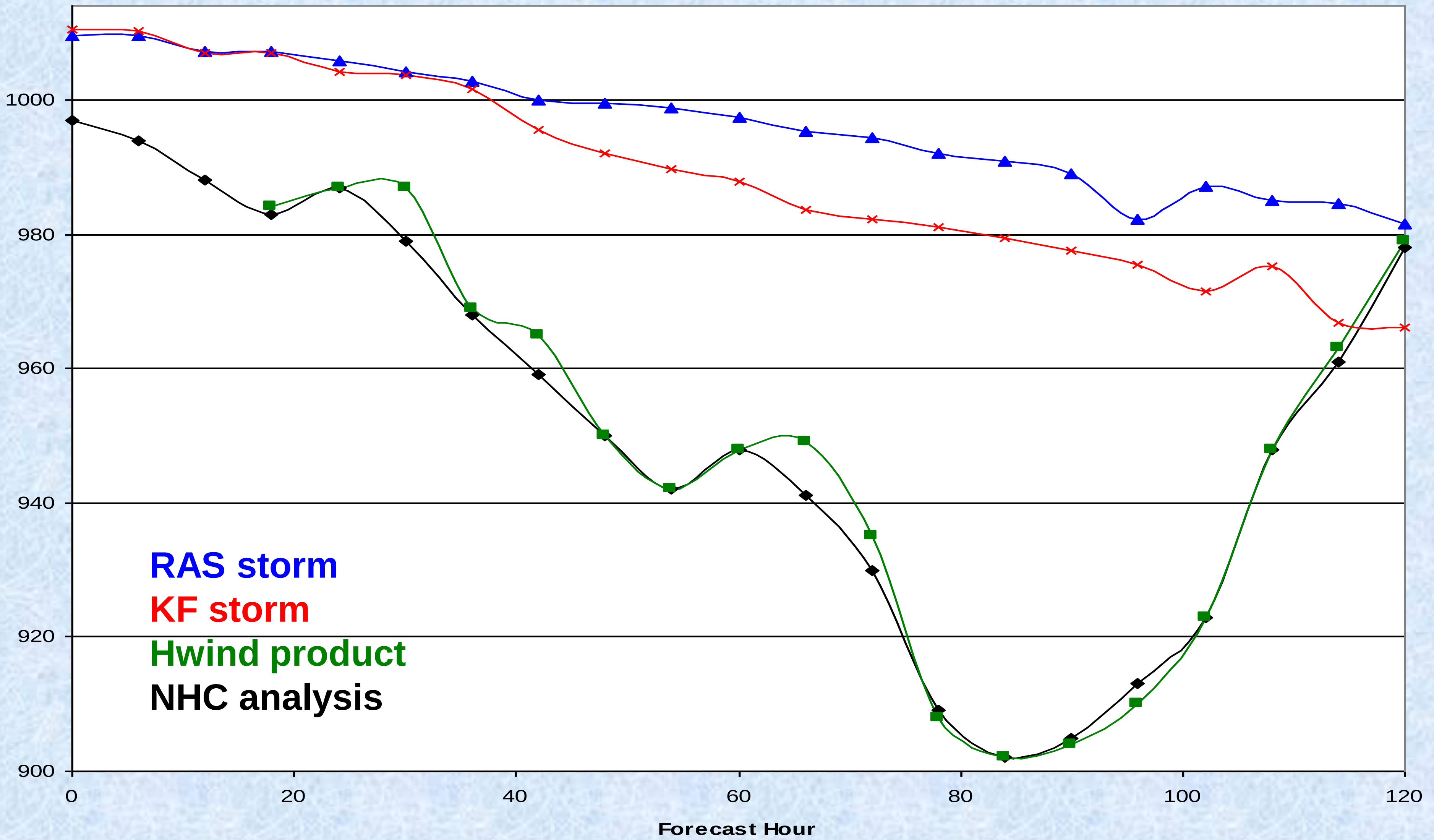


Initial Conditions

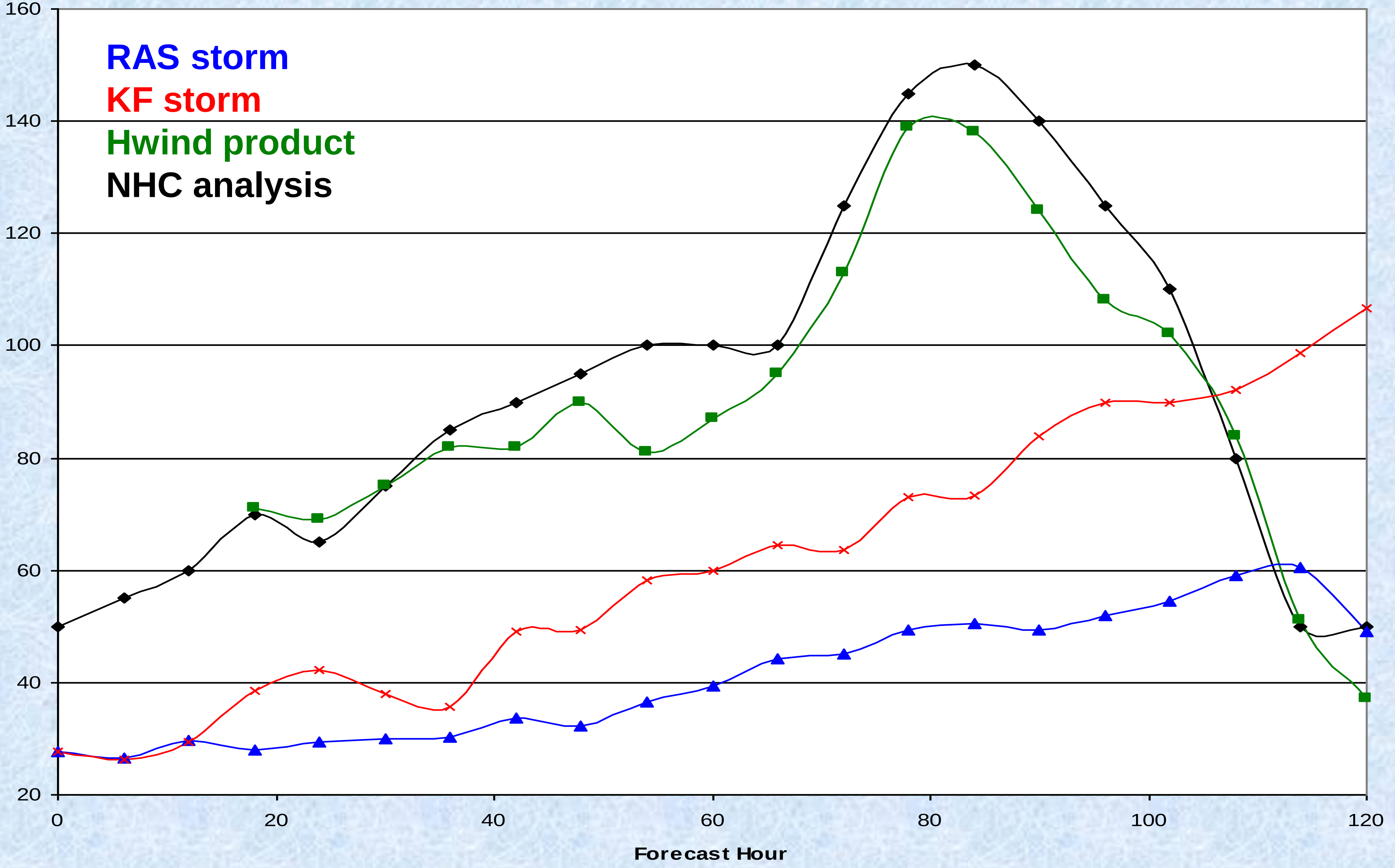
- Initial condition for all runs is the result of a 6-hr standard GEOS-5 (i.e., with RAS) 0.25-deg forecast from GFS initial condition.
  - Our initial condition is 25 Aug 06z.
  - Max wind 27 kts; min SLP 1010 mb (vs. Best Track 50 kts, 997 mb)
- Storm was offshore Florida (Atlantic side)
- Forecasts were made with 0.25-degree resolution with RAS and with Kain-Fritsch implemented, respectively
- It is noted (with apologies) that some results shown here are from a near-current version of GEOS-5, while others are from an older version ("patch 11"). While details of the fields may vary slightly, the results' general descriptions and conclusions do not change.



Minimum SLP

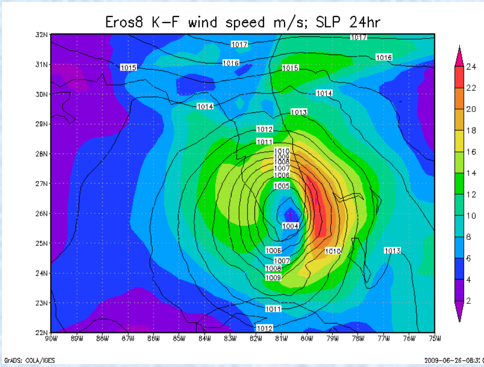

1000
980
960
940
920
900
0
20
40
60
80
100
120
Forecast Hour
RAS storm
KF storm
Hwind product
NHC analysis

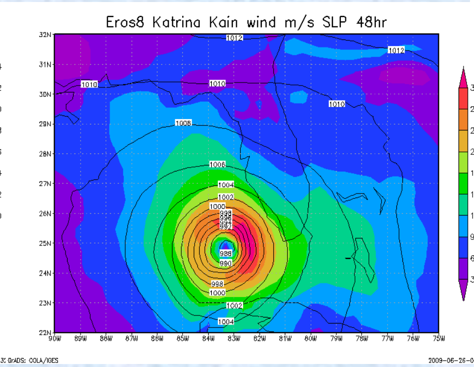
Max surface (10m) wind (knots)

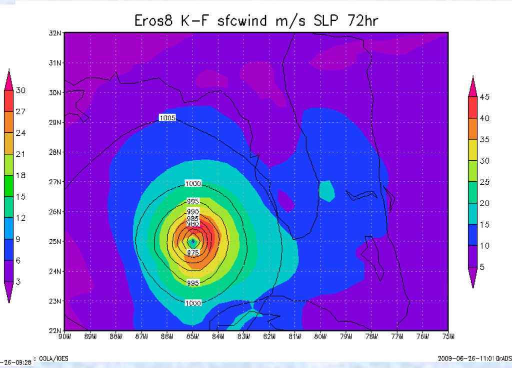


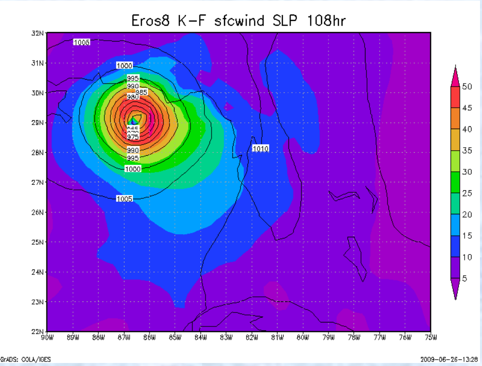
Surface (10m) wind speed, SLP fields

With Kain-Fritsch scheme:

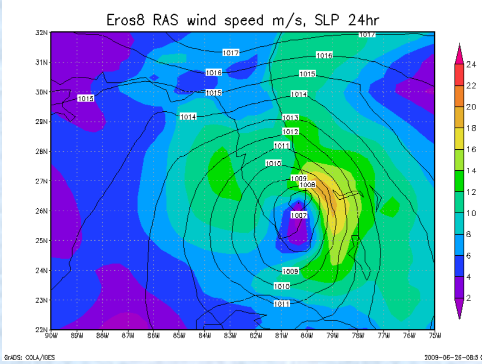


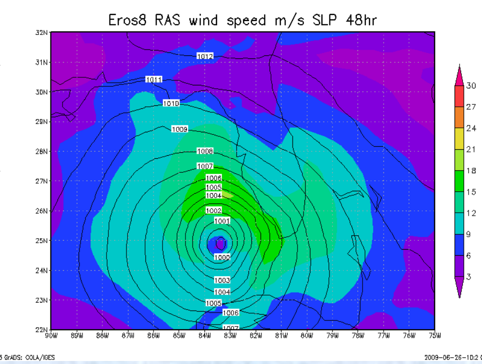


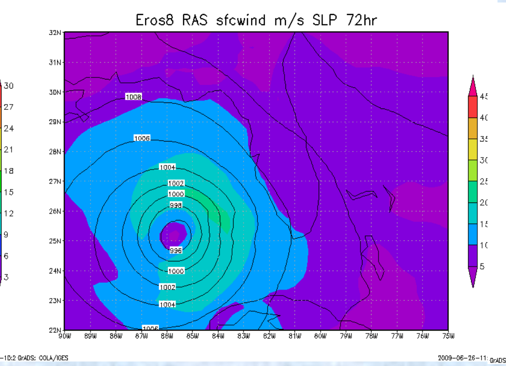


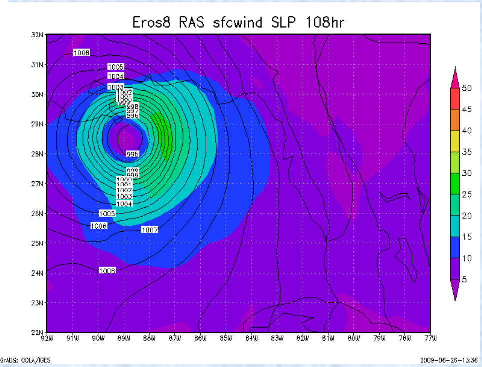


With RAS scheme:

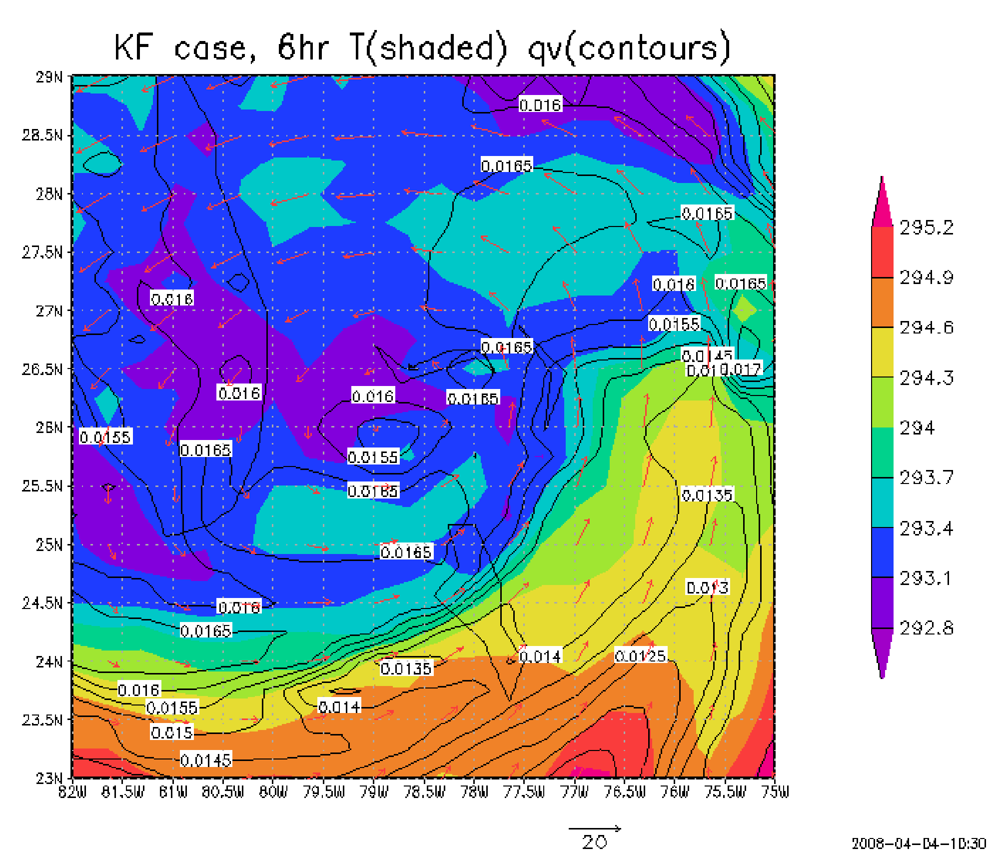


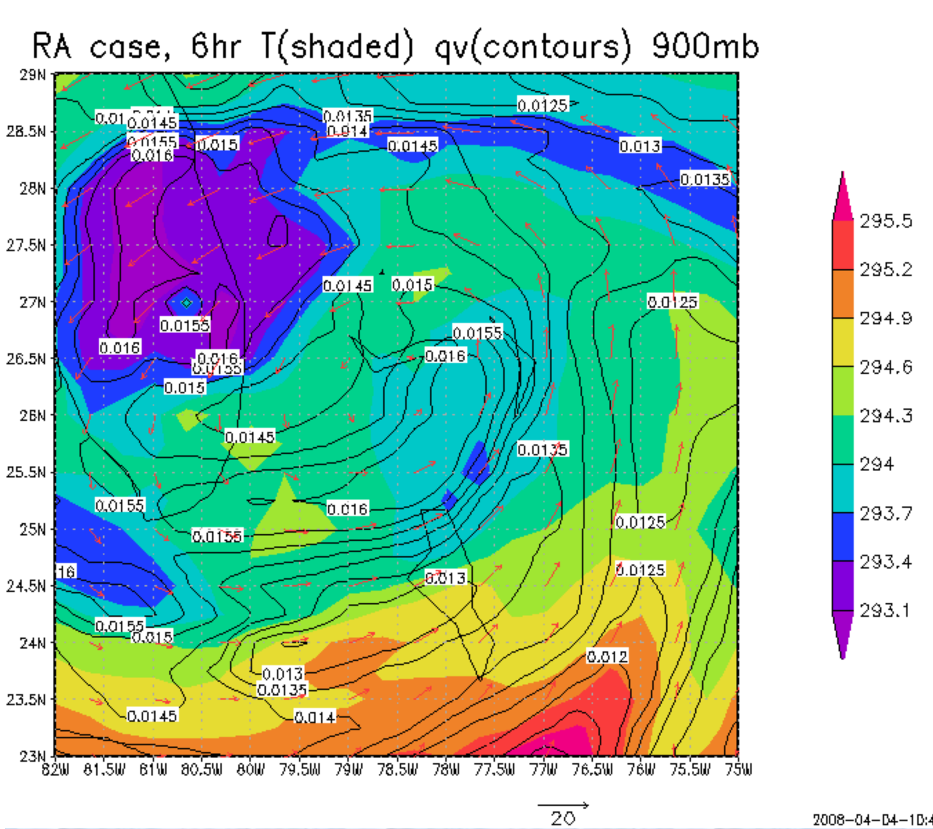






900 mb T, water vapor at 6 hours



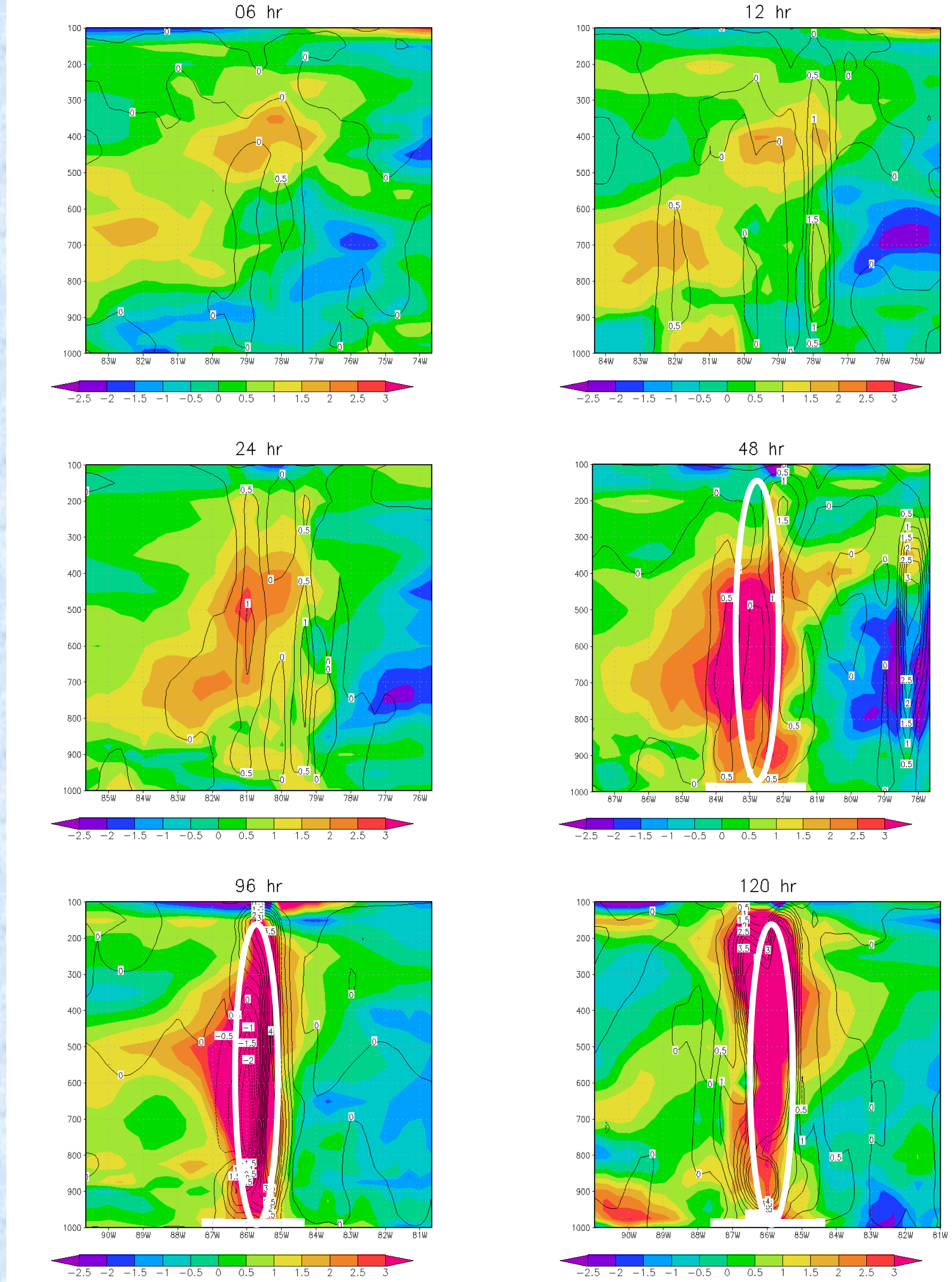


KF

W-E Cross-section

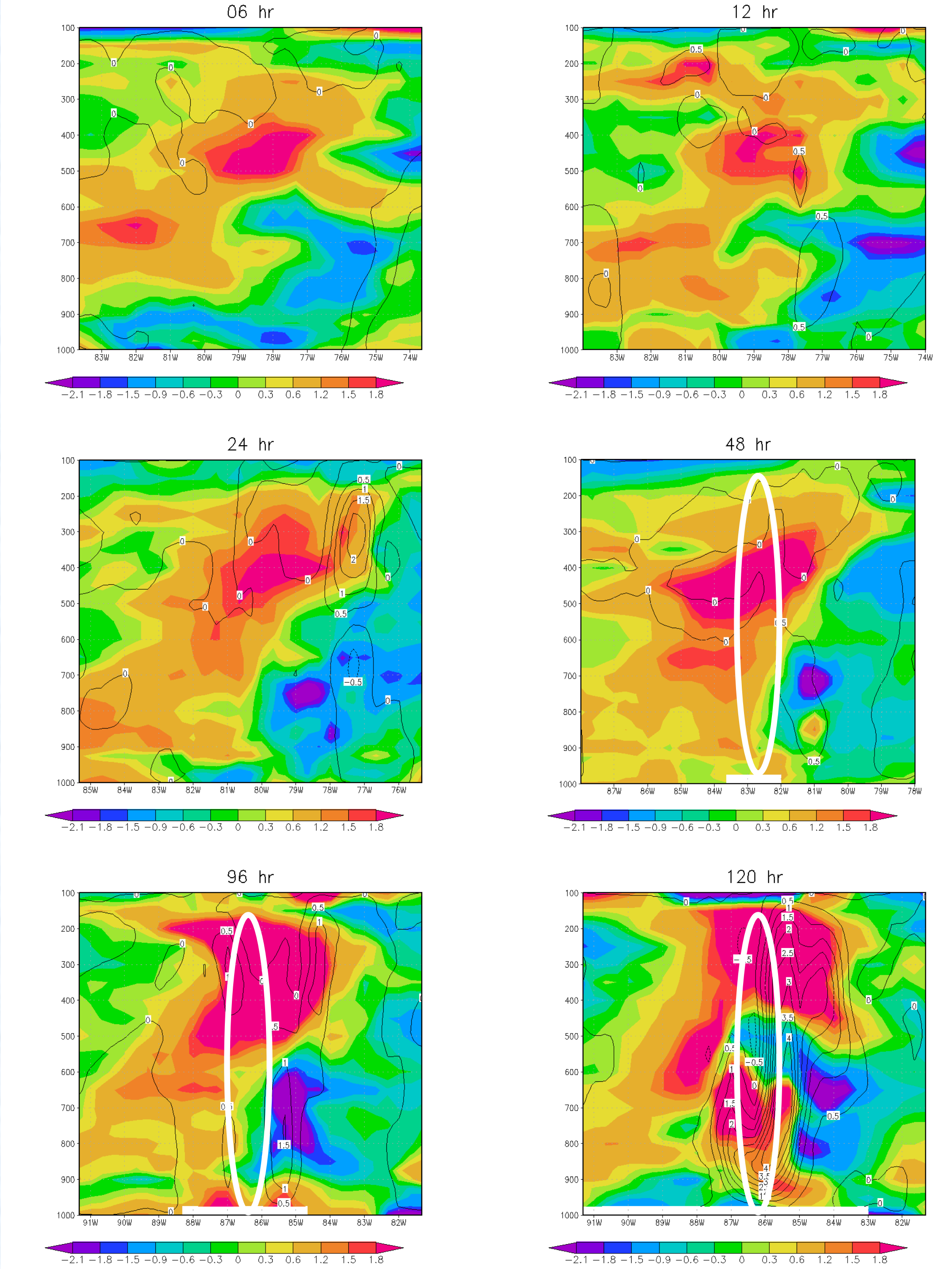
Temperature anomalies and vertical velocities through storm center.

Note color contour interval.



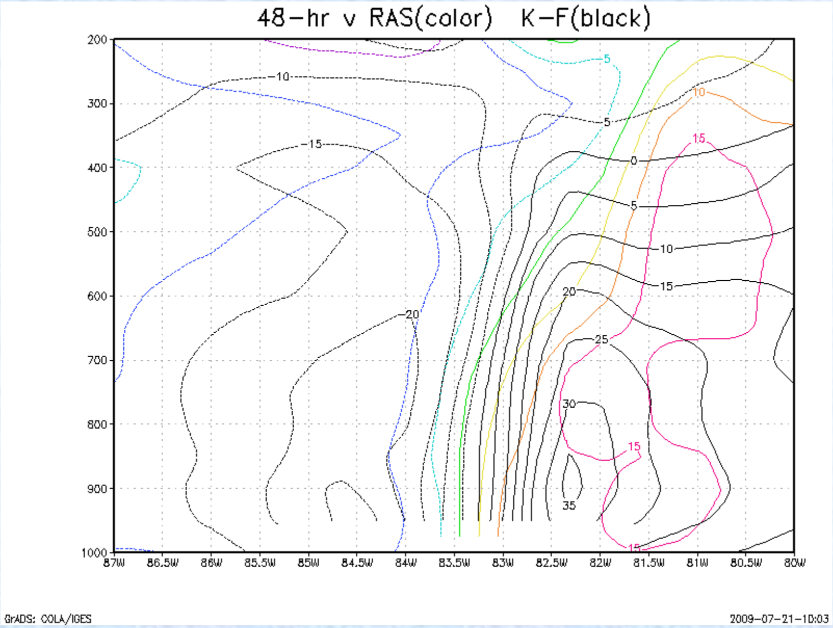
RAS

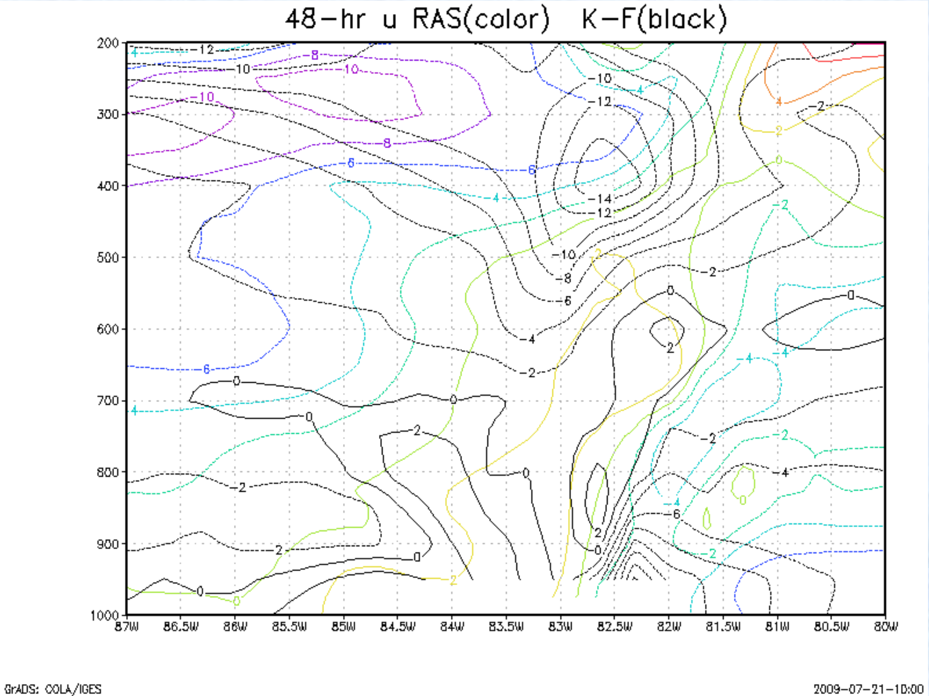
Temperature anomalies and vertical velocities.



Comparison of RAS, K-F wind fields at 48 hours

- Right: Tangential wind in W-E cross-section through storm center



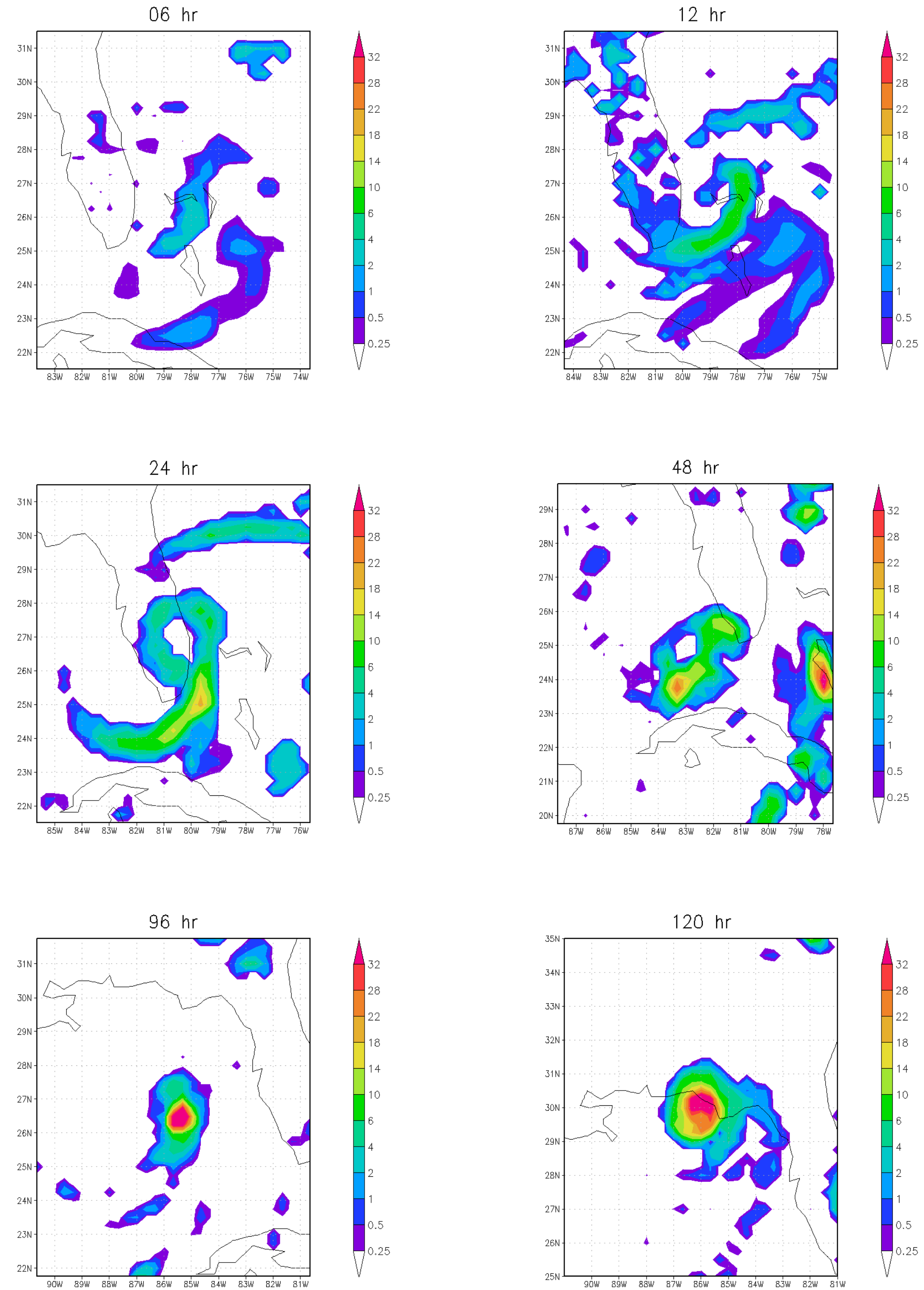


- Left: Radial wind (u) in W-E cross-section through storm center

KF

Precipitation

6-hour averages, centered on the given forecast time, in mm/hour



RAS

Precipitation

6-hour averages,
centered on the
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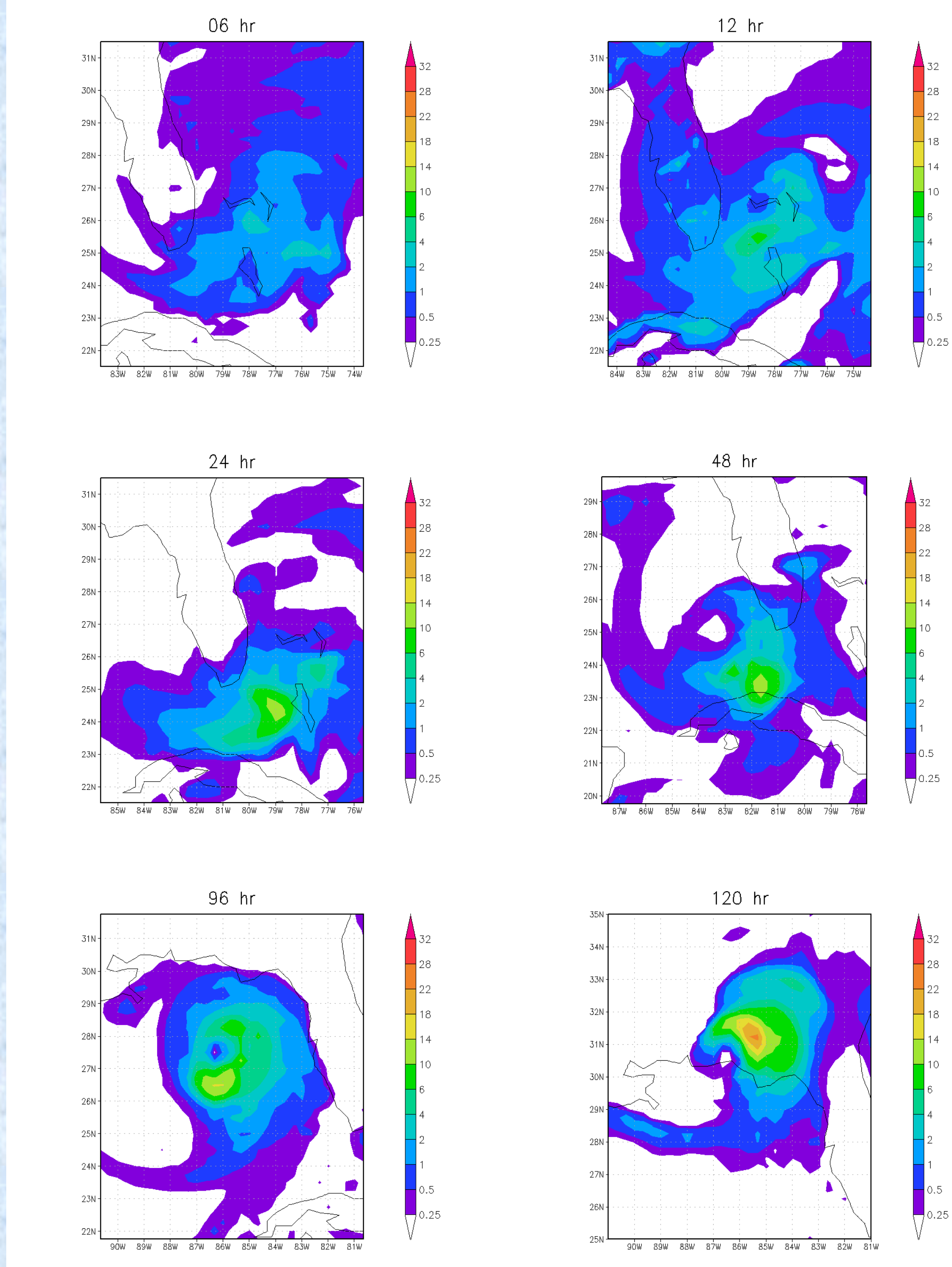
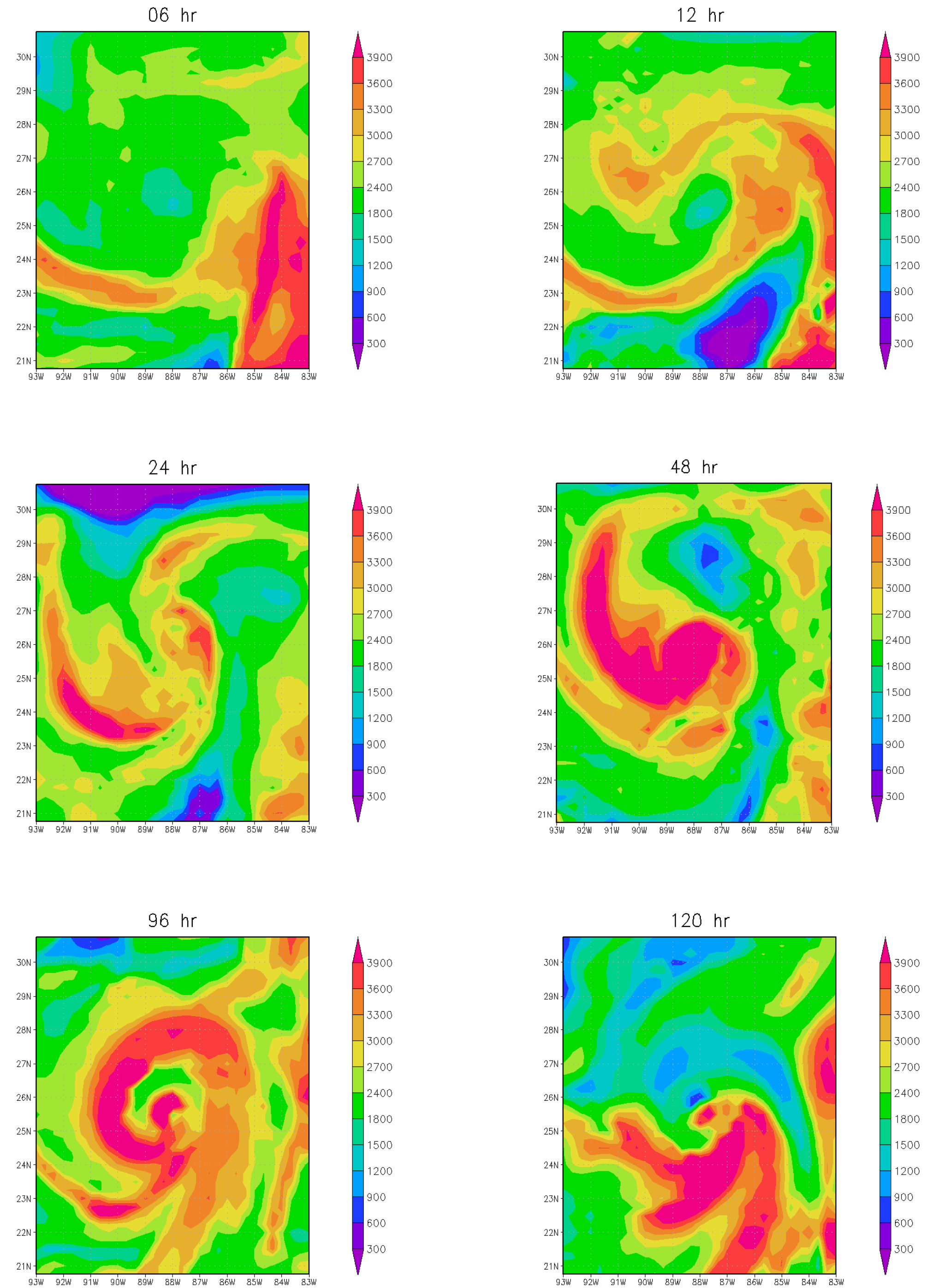
in mm/hour



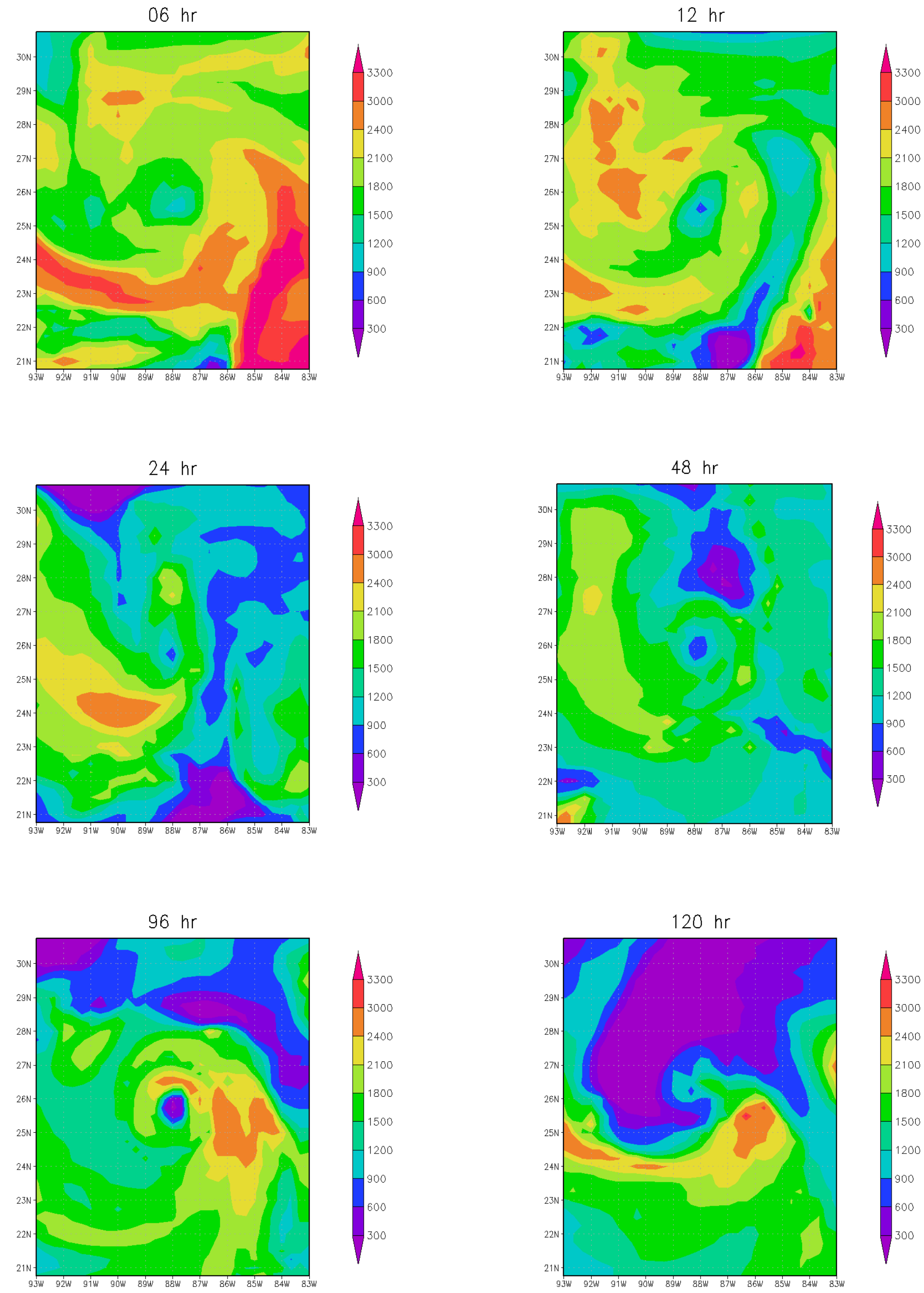
KF

Surface-based CAPE. Units are Joules per kilogram. Note: Lat and lon labels on this and the next figure are incorrect. Figures are storm-centered, with fictitious lat & lon.

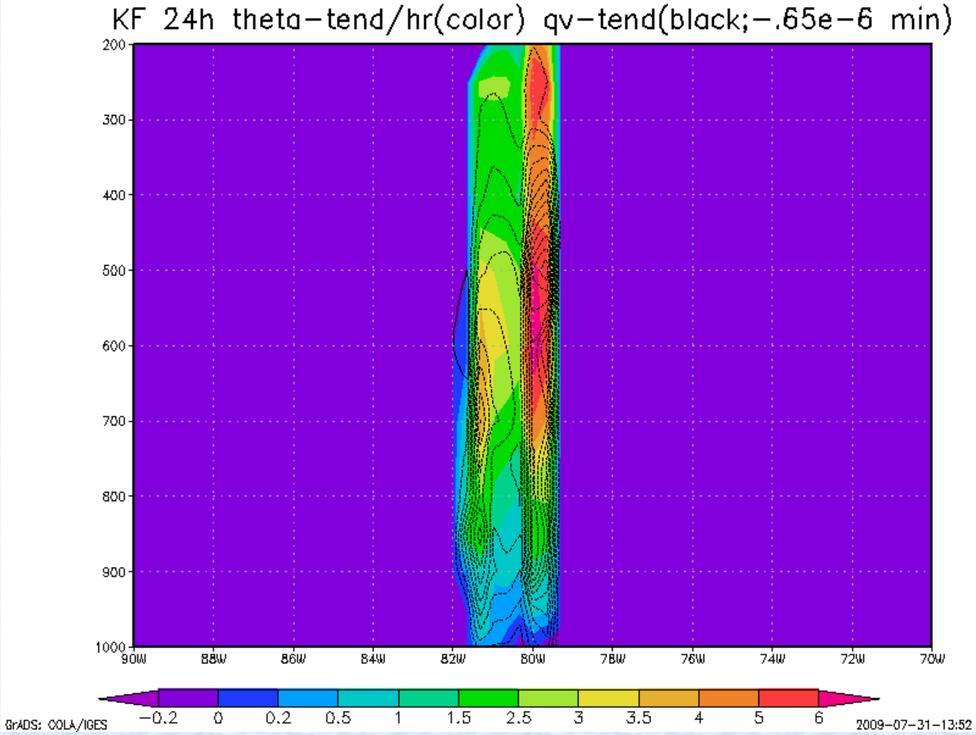


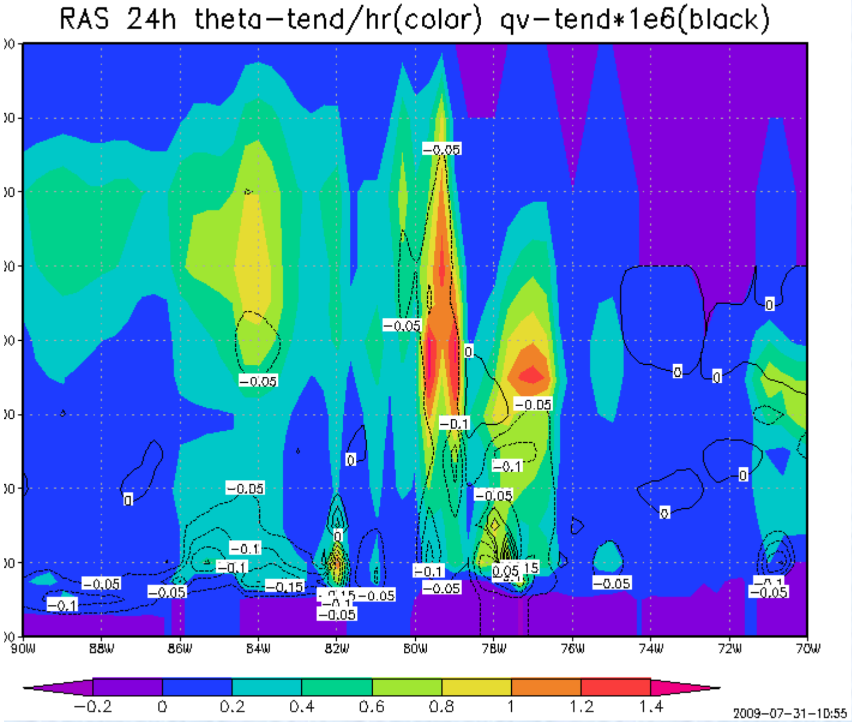
RAS

Surface-based CAPE. Units are Joules per kilogram.

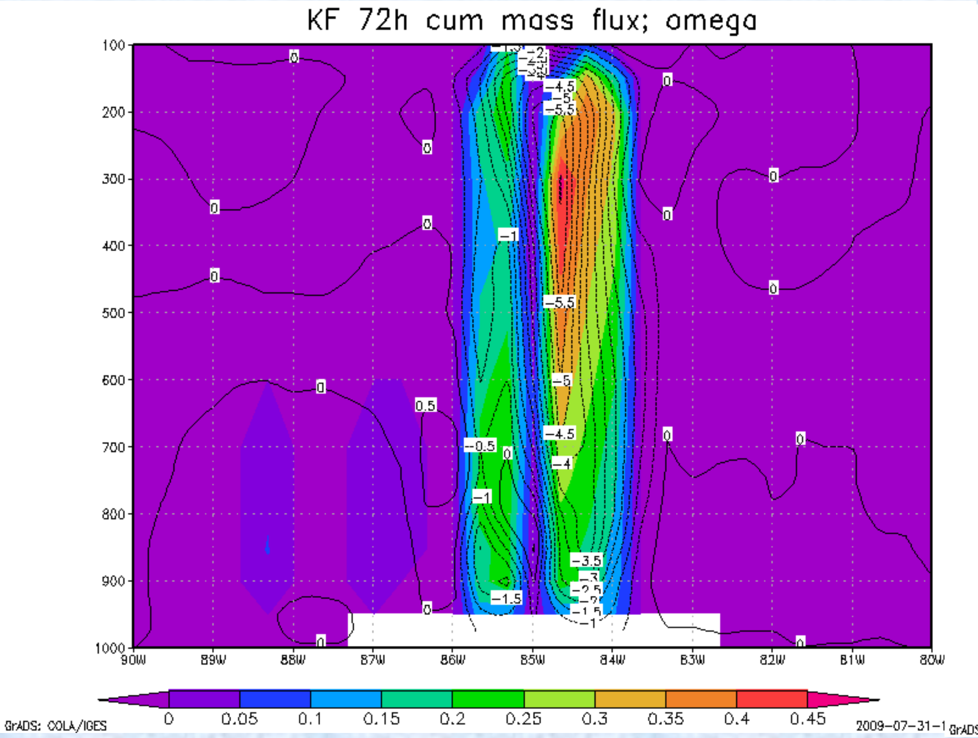


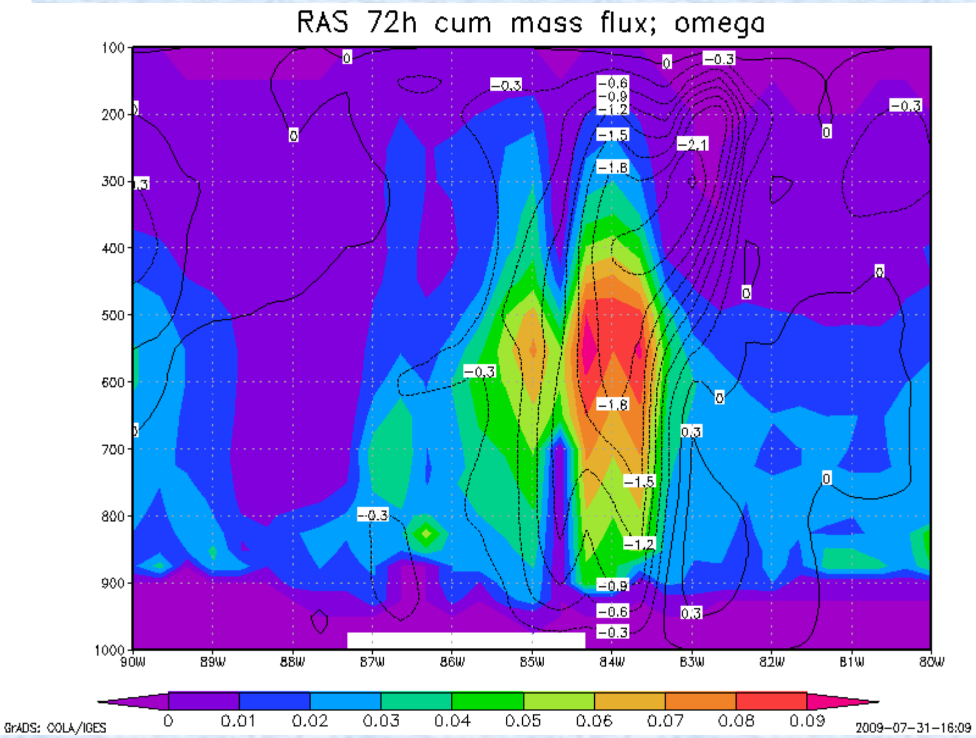
Potential temperature and water vapor tendencies due to moist processes at 24 hours



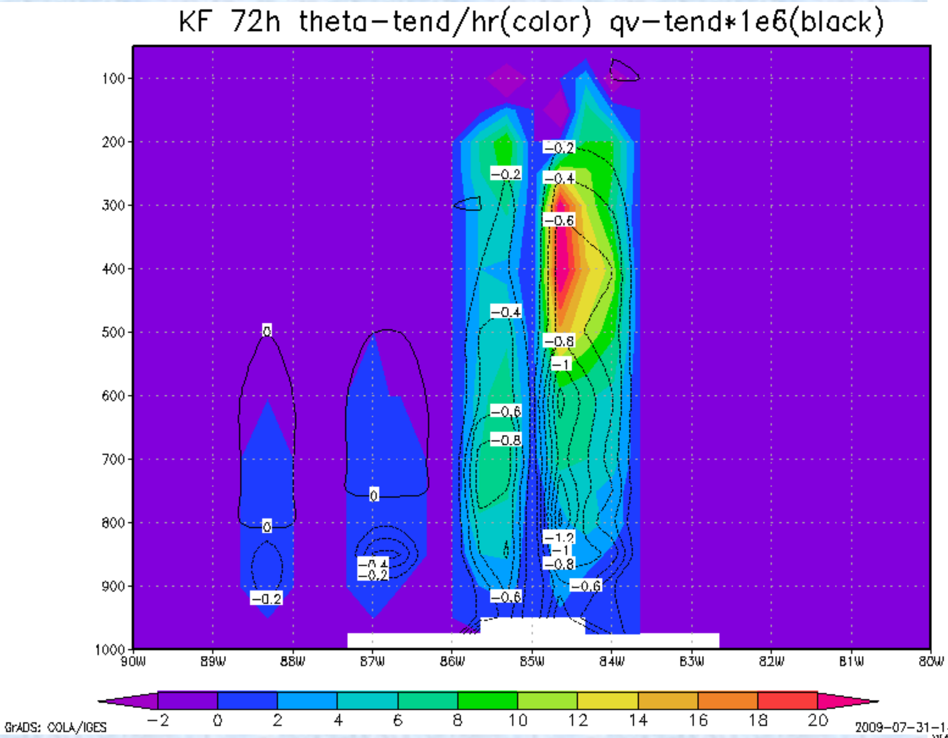


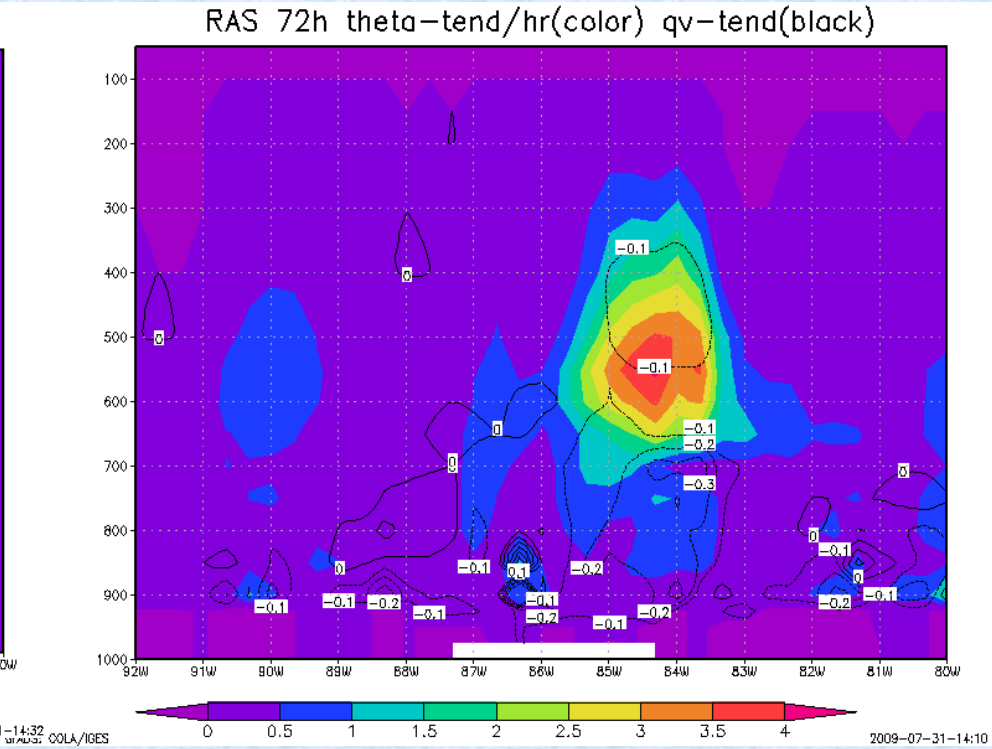
Cumulus mass flux, omega at 72 hours





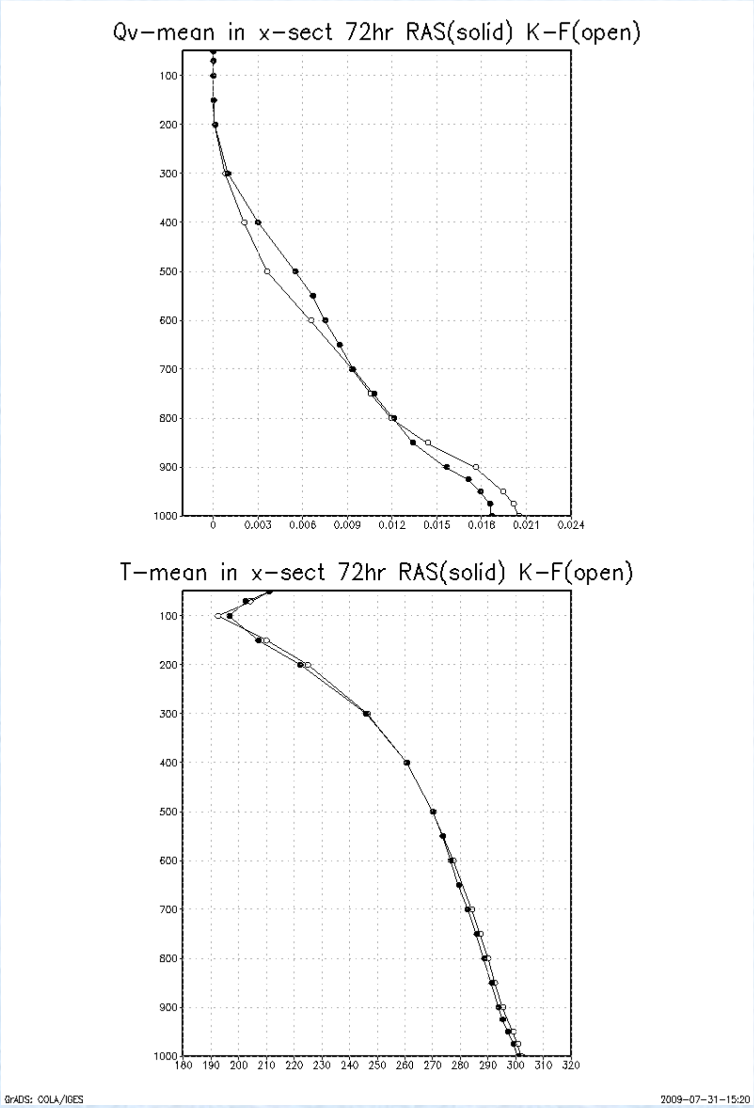
Temperature and water vapor tendencies at 72 hours





Cross-section mean temperature, water vapor profiles at 72 hours

- RAS: Drying in lower layers, moistening above. Slight cooling below, lowering the lapse rate (i.e. raising the static stability) in the lower/middle troposphere.



Conclusions

- Global forecasts were made with the 0.25-degree latitude version of GEOS-5, with the RAS scheme and with a modified Kain-Fritsch scheme. Examination was made of the Katrina (2005) hurricane simulation.
- Replacement of the RAS convective scheme with the K-F scheme results in a much stronger and compact Katrina, closer to reality by those measures.
  - Still, the result is not as vigorous as reality. In terms of wind maximum, the gap was closed by ~50%.
- The Kain-Fritsch scheme permits development of an effective secondary circulation, resulting in a well-developed warm-core storm.
  - The structures of the Kain-Fritsch q and T tendencies are tall and largely confined to the vortex region, the latter point of which is probably due to the use of a trigger function which is dependent in part on the grid-scale convergence below the LCL.
- The suppressed storm development in the RAS case seems to be due to the RAS scheme drying out the boundary layer and lower free troposphere, thus hampering the grid-scale secondary circulation and attending cyclone development.
  - The RAS case did not develope a full warm core until near landfall.
  - The RAS convective tendencies were not well co-located with the inner vortex region, and tend to be unorganized (both vertically and horizontally) throughout the storm.
- Not shown here: The K-F scheme also resulted in a more vigorous storm than when GEOS-5 is run with no convective parameterization (although the latter case was much stronger than the RAS case).
- Also not shown: An experiment in which the RAS firing level was moved up by 3 model levels resulted in a stronger, warm-core storm, though still not nearly as strong as the K-F case.
- Effects on storm track were noticed, but not studied.
- Further simulations of other tropical cyclones needed before general conclusions can be made
- Experiments with other convective schemes (e.g. Emanuel) would be desirable.